Corrosion Damage and the Shear Capacity of Coastal Bridges

Gordon Holcomb, Steve Cramer, Bernie Covino, Jim Russell, Sophie Bullard, and Margaret Ziomek-Moroz

NWTC, Corvallis OR, 2/7/02

Big Creek

Spencer Creek

Corrosion of Reinforced Concrete Bridges on Oregon Coast

Replacement Bridges			
Alsea Bay	1991	$42M	
Rocky Point Viaduct	1995		
Brush Creek	1998	$2M	SS Rebar
Smith River	1999	$8M	SS Rebar
Cooks Chasm	2002	$3M	
Haynes Inlet	2002	$11M	SS Rebar

Corrosion of Reinforced Concrete Bridges on Oregon Coast

Thermal Spray Rehabilitation (CP)		
Cape Creek	1991	$3M
Yaquina Bay	1994 & 1997	$13M
Depoe Bay	1995	$4M
Big Creek	1998	$4M
Rocky Creek	2001	$4M
Cummins Creek	2001	$2M
Rogue River (Patterson)	2003	$18M

Critical Concerns

- What leads to extensive corrosion damage and early replacement?
- How should bridges be renovated?
- How should new bridges be constructed?
- What is the capacity of bridges with corrosion damage?

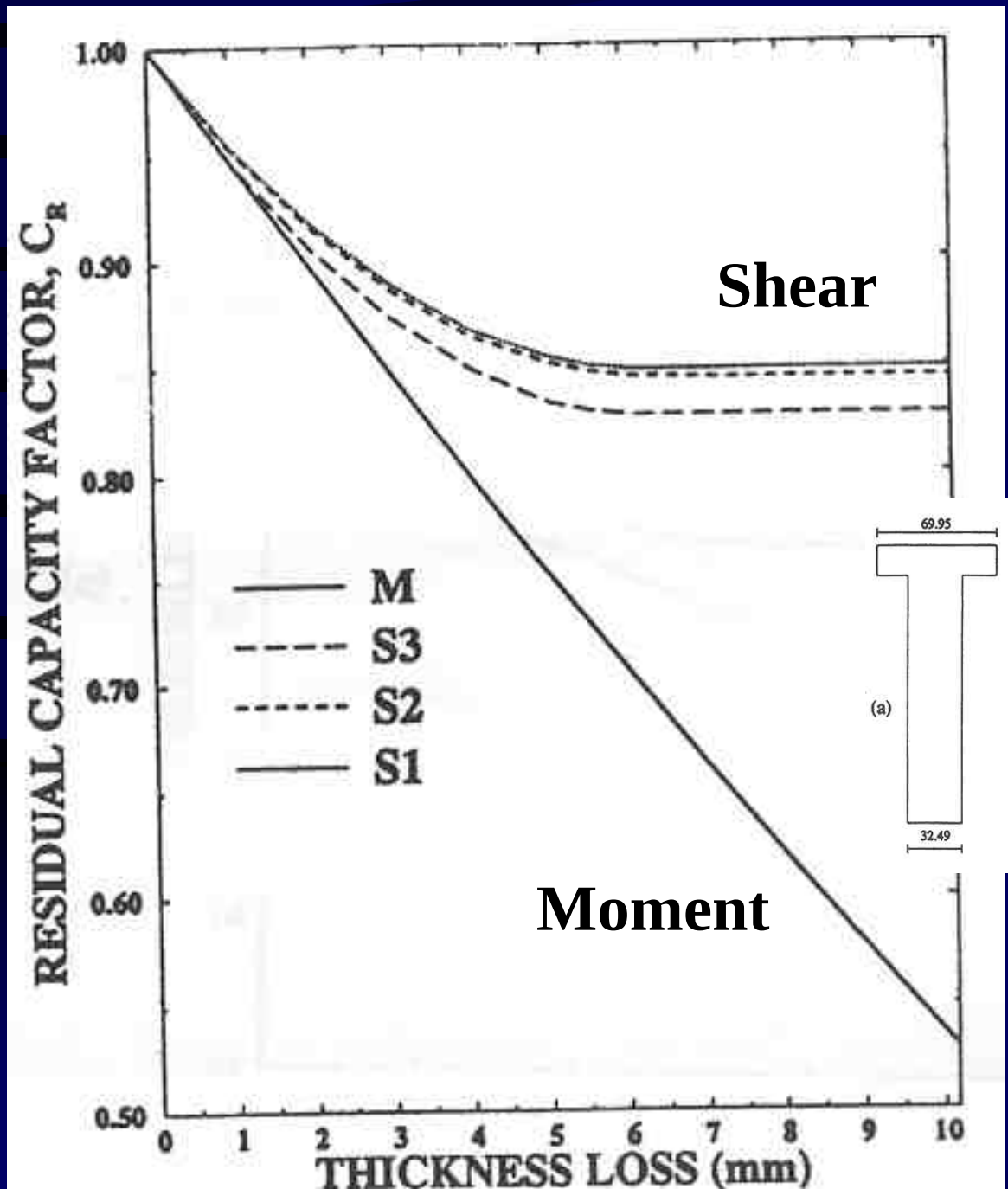
Capacity of Corroded Bridges

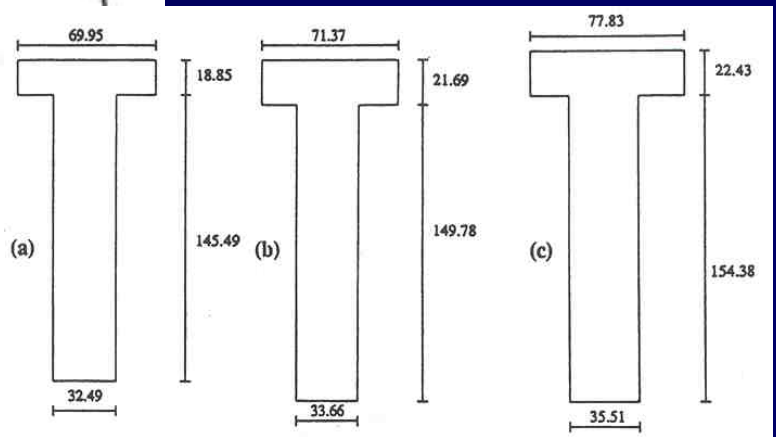
- Brush Creek Bridge
  - Replaced after extensive corrosion damage
  - Yet a beam tested during removal had 76% of its flexural capacity remaining.
- Corrosion to longitudinal rebar
  - Effects on flexural strength loss are calculable
- Corrosion to shear stirrups
  - Effects on shear strength loss more complex

Shear Strength Loss

- Even with complete section loss there is still shear strength remaining in the concrete
  - Aggregate interlock
  - Dowel action of the longitudinal steel
  - Shear resistance of the compression zone
- These factors, and those from remaining shear stirrups, are not easily calculated

Frangopol et al., 1997





Research Plan

- Cast Beams
- Corrode Beams
- Shear Strength Testing
- Analysis
- Translate Results to Practice

Cast Beams

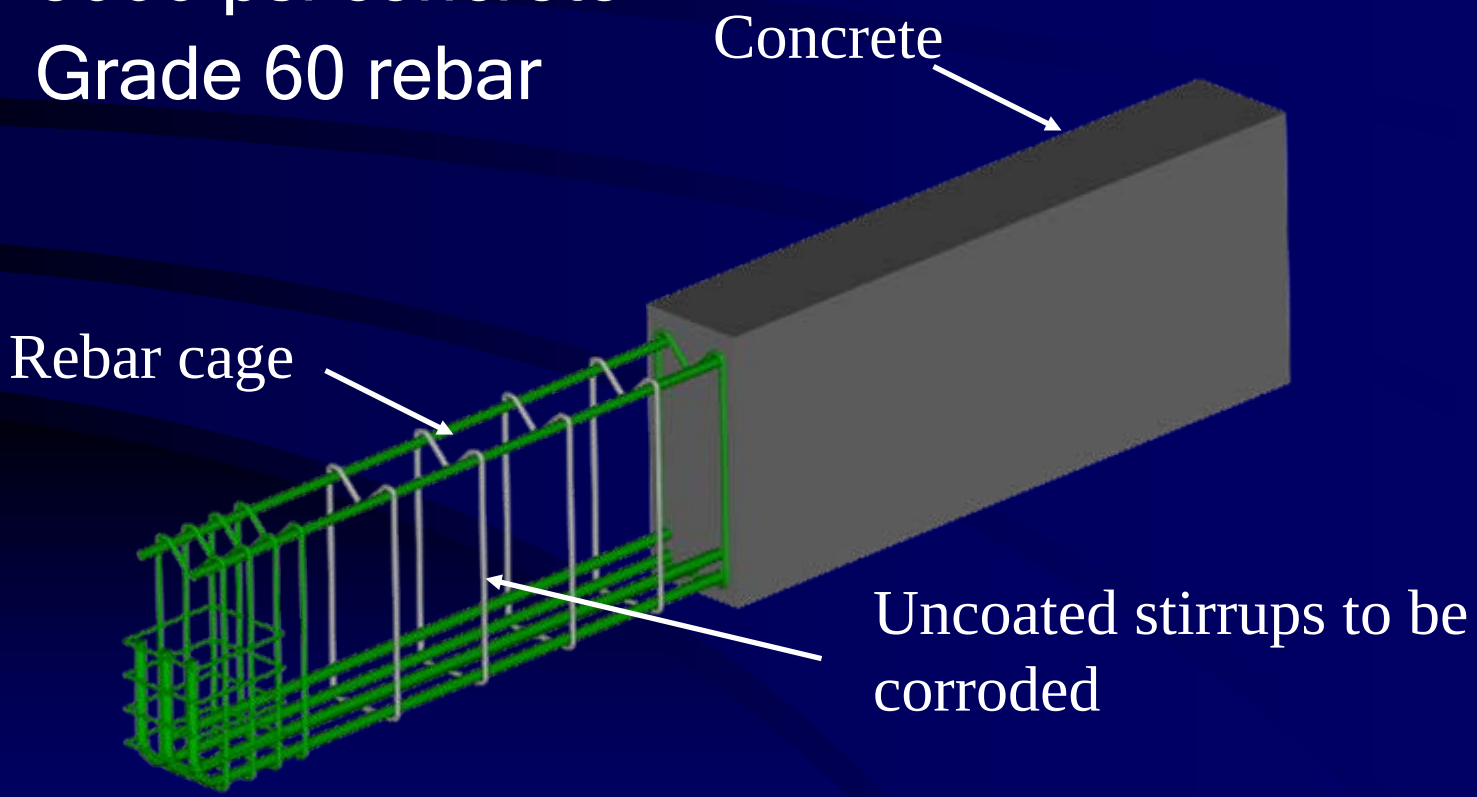
- Designed as 1950s vintage beams
  - 10” x 24” beams
  - 10” and 12” shear reinforcement spacing
  - Target compressive strength of 3000 psi
  - Water to cement ratio of 0.45
  - 5 lb/yd^3 of Cl^- in mix (as NaCl)
  - Shear reinforcement epoxy coated except for those to be corroded

Cast Beams

- Beam types
  - Rectangular beams
  - Interior T-beams
  - Exterior T-beams
- 10” and 12” stirrup spacing
- 4 damage states of 0%, 20%, 40%, and 80% shear reinforcement section loss
- Total of 14 beams
- 10 beams to be corroded

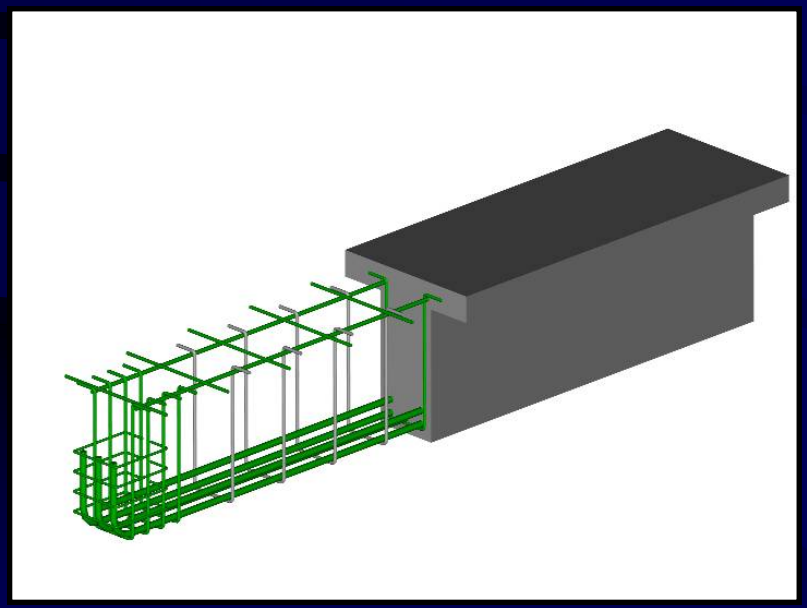
Rectangular Beam

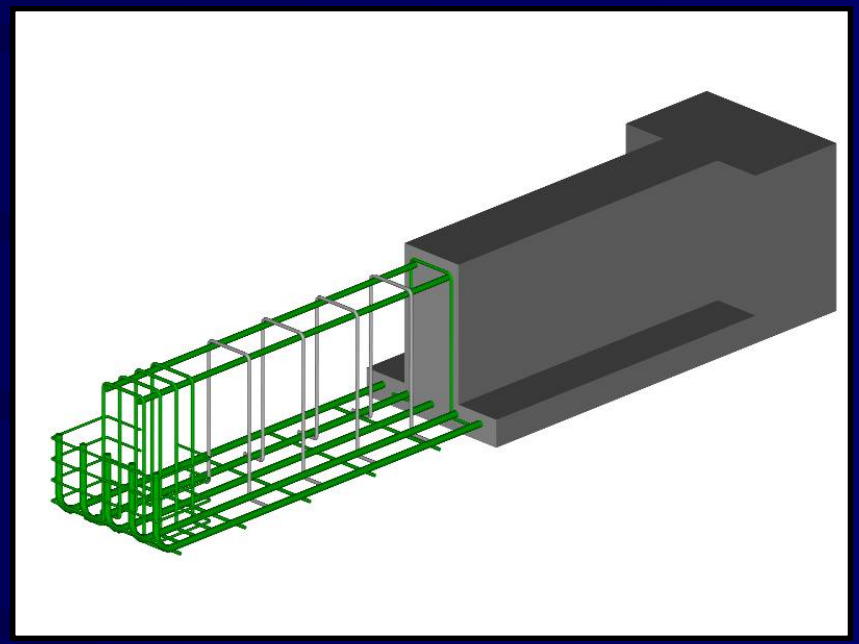
- 24 in x 10 in x 10 ft 5 in beam
- 3000 psi concrete
- Grade 60 rebar



T-Beams

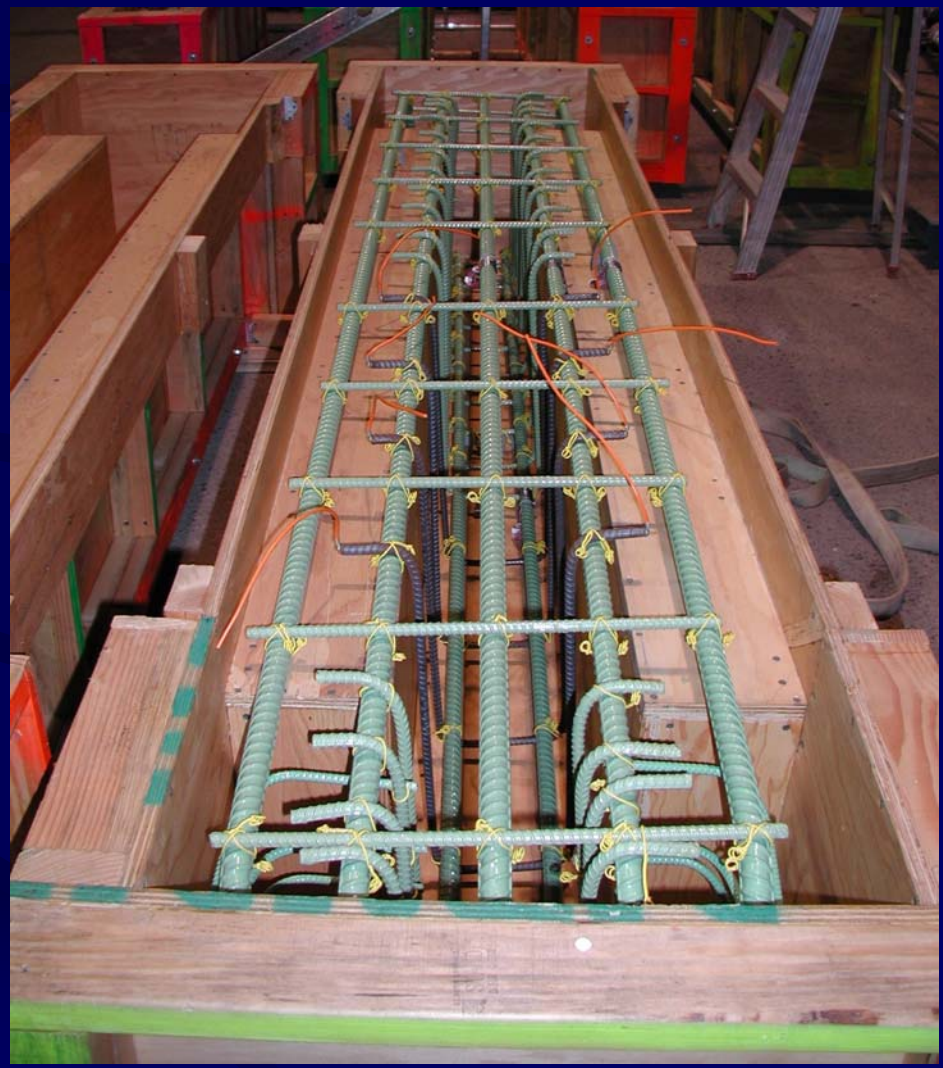
Exterior





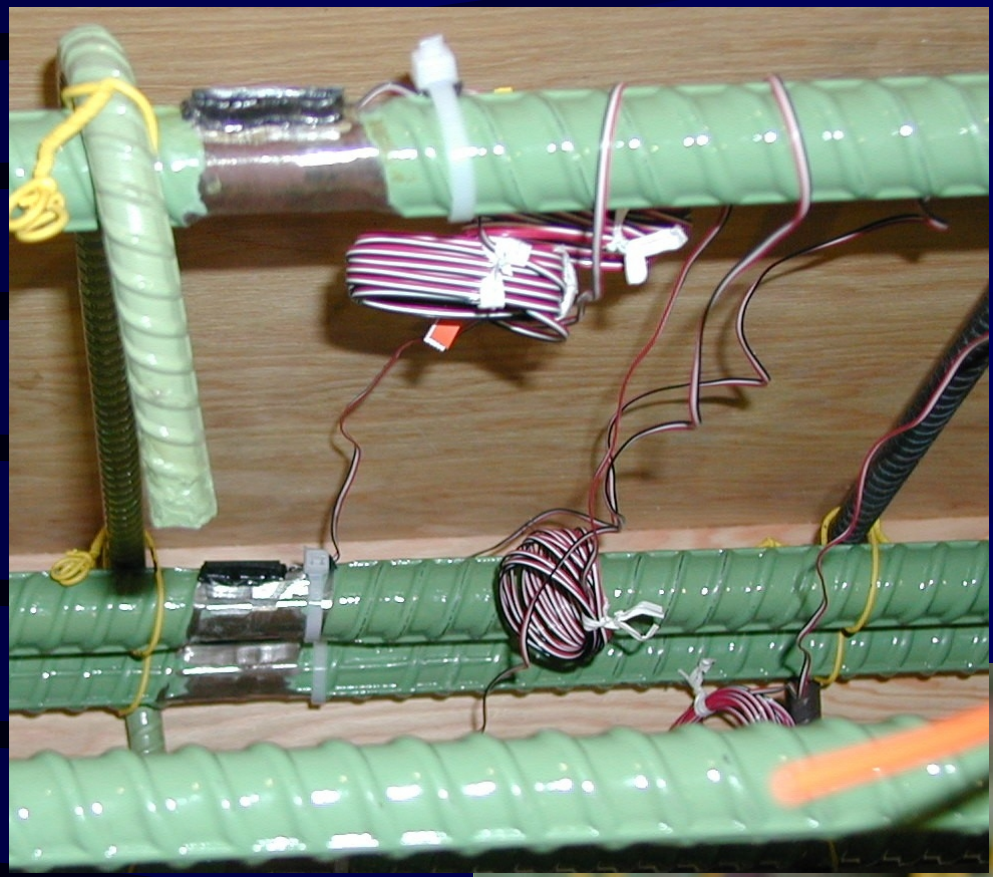
Interior

Rectangular and “T” Beams



Containment

Wiring

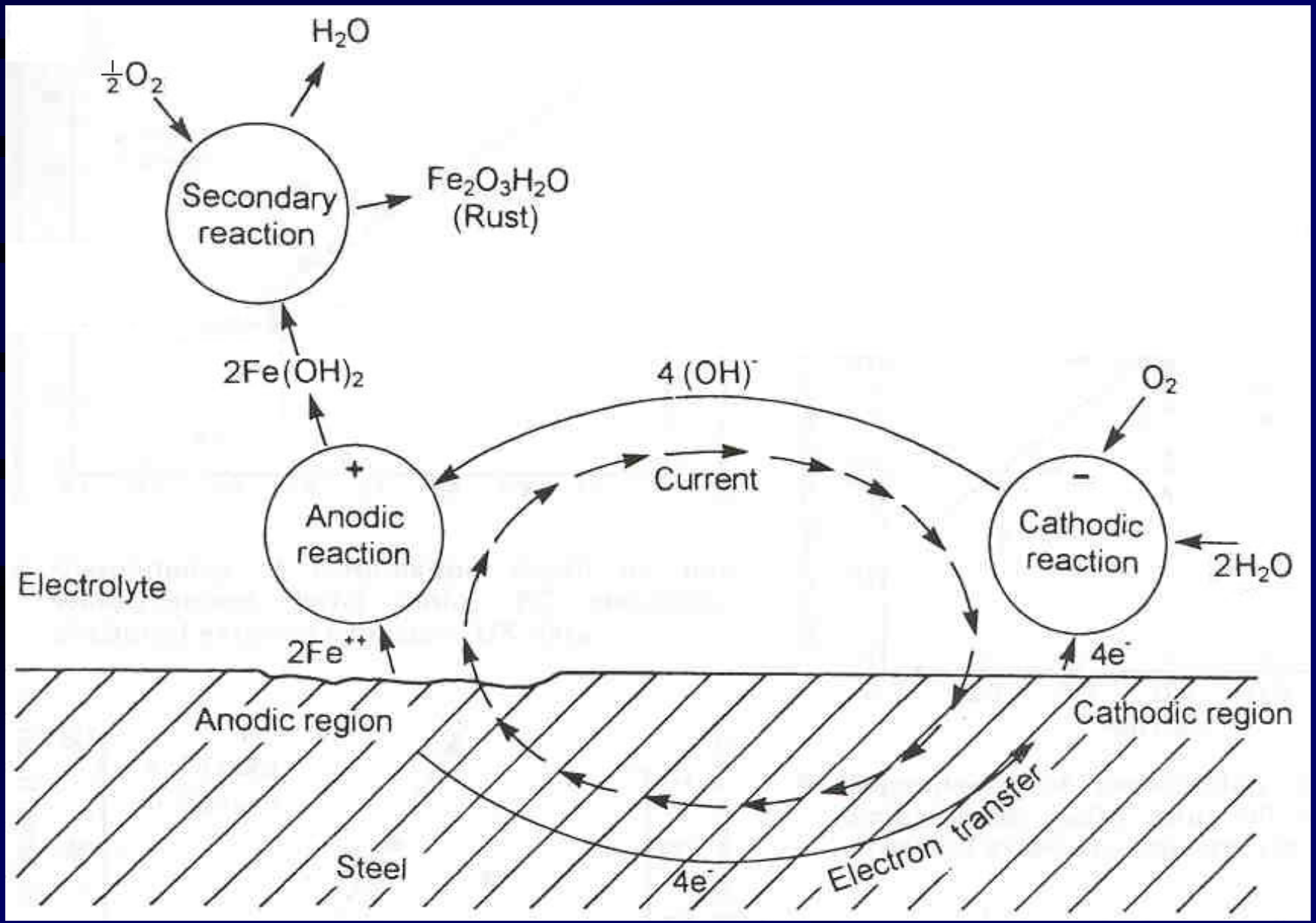


Casting Beams

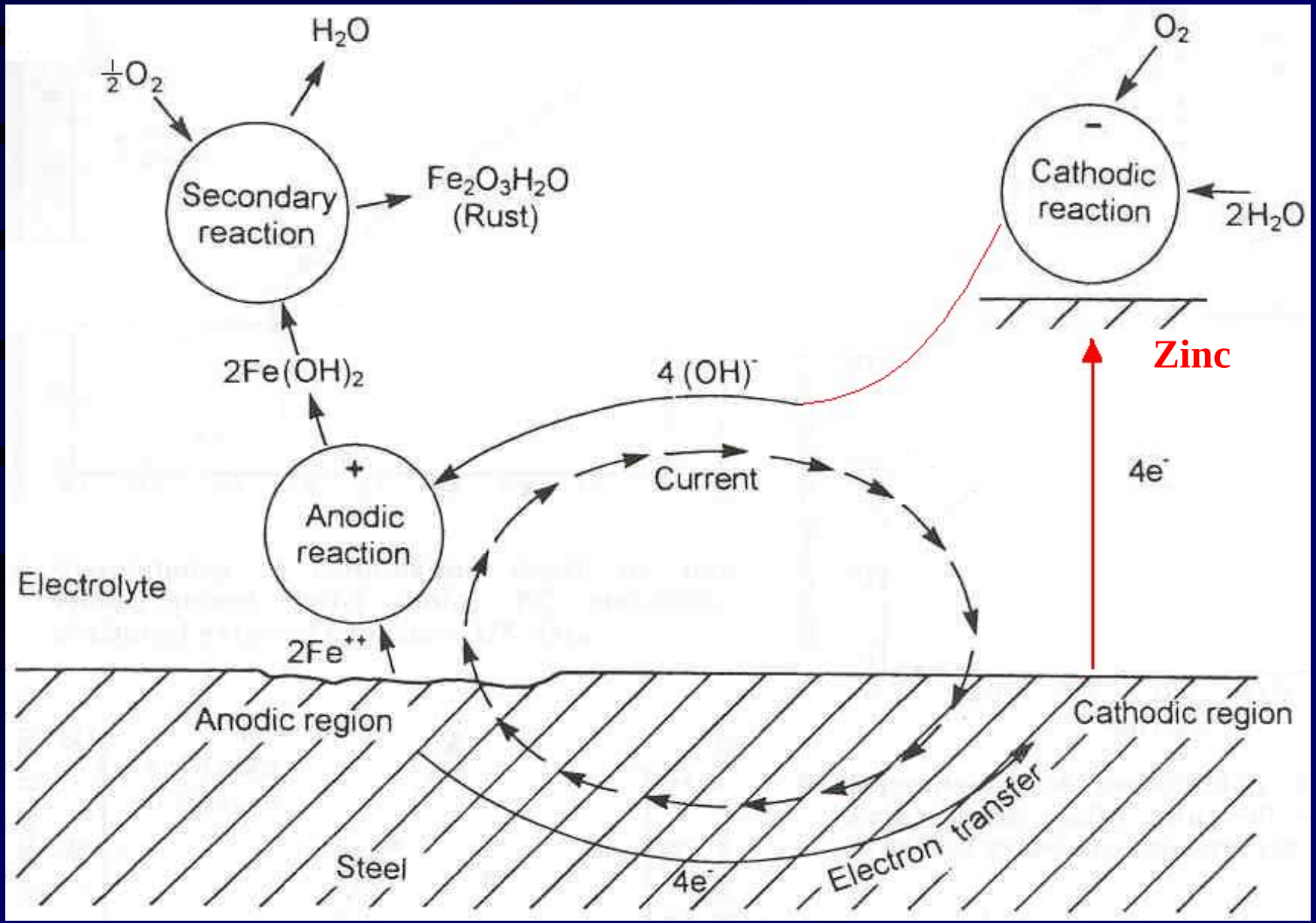
Corrode Beams

- Corrosion process: natural and accelerated
- Initial investigation to determine current density levels using small cylinders
- Beam corrosion

Corrosion Reactions



Remote Cathode



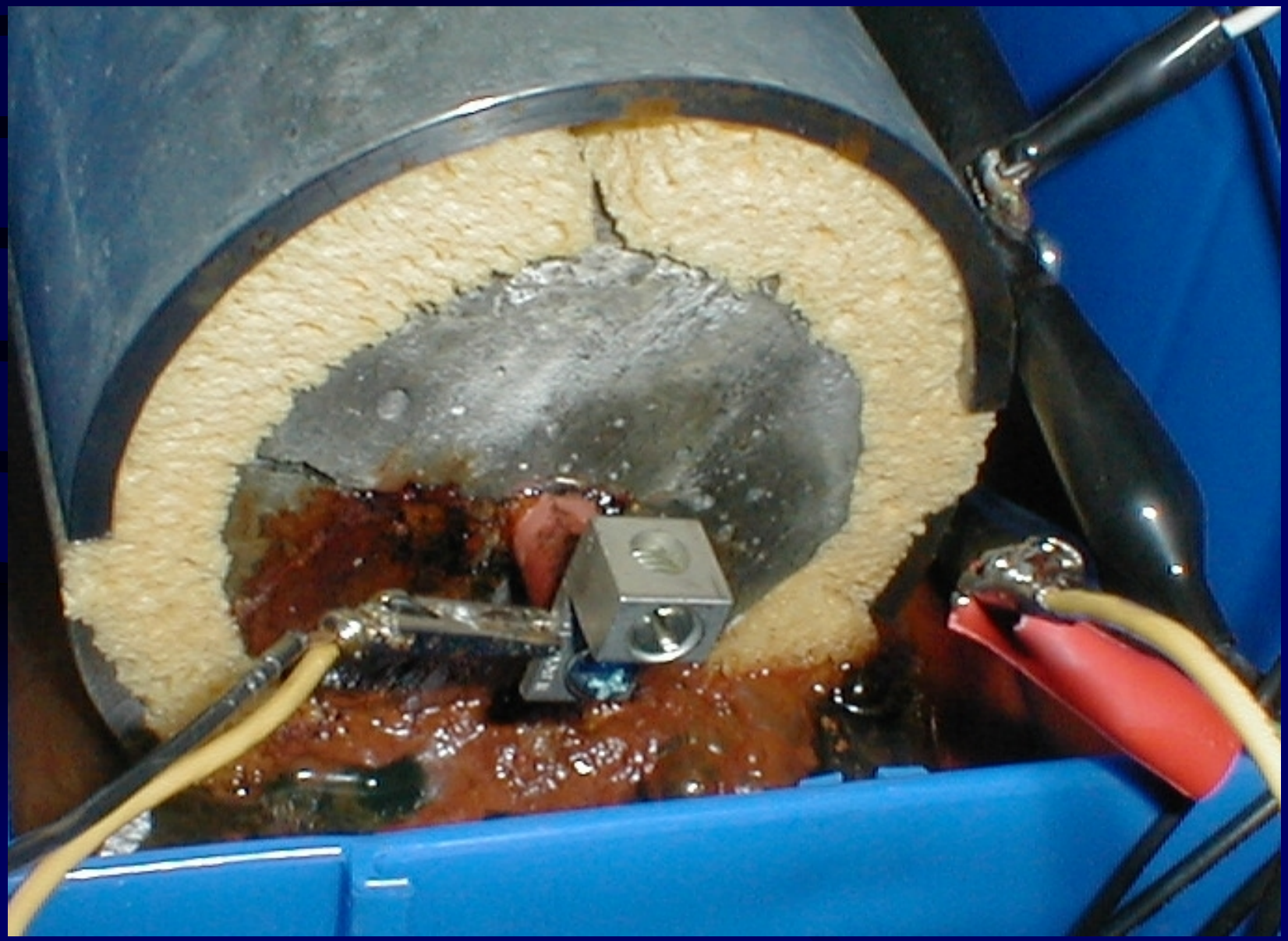
Current Density Invesigation

- Small cylinders corroded at 3 current densities of about 0.3, 0.6, and 1.7 mA/cm^2
- Corroded to 4 different levels, between 10% to 80% section loss

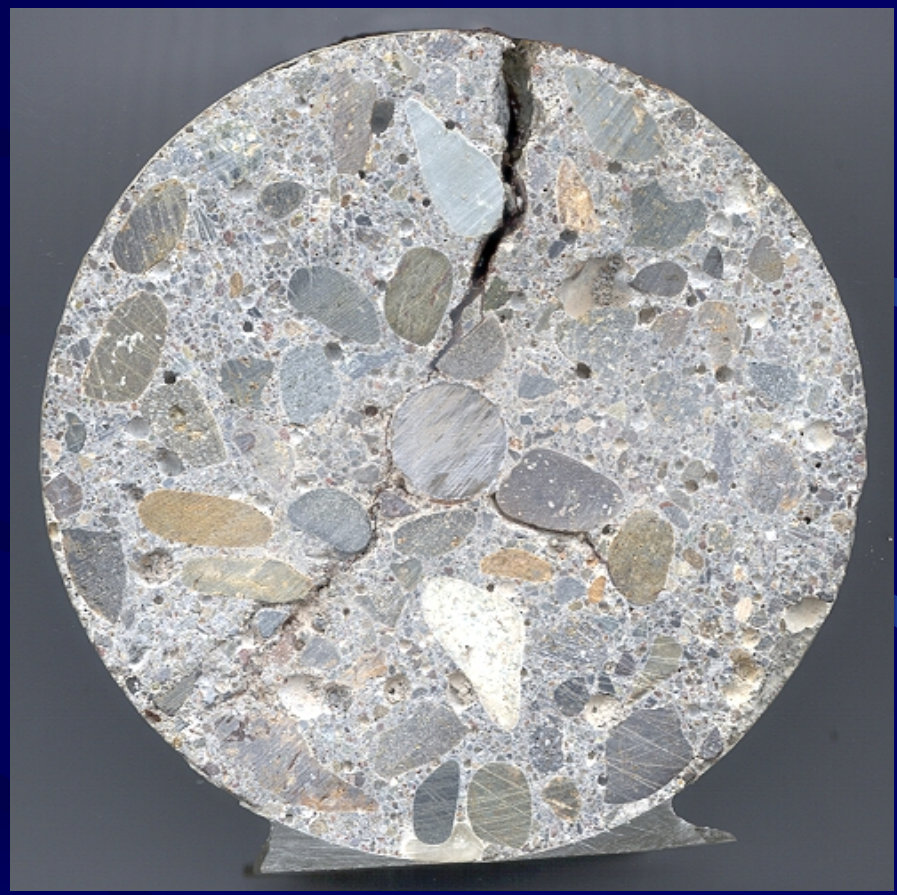
Casting Cylinders

Cylinder Corrosion - Setup

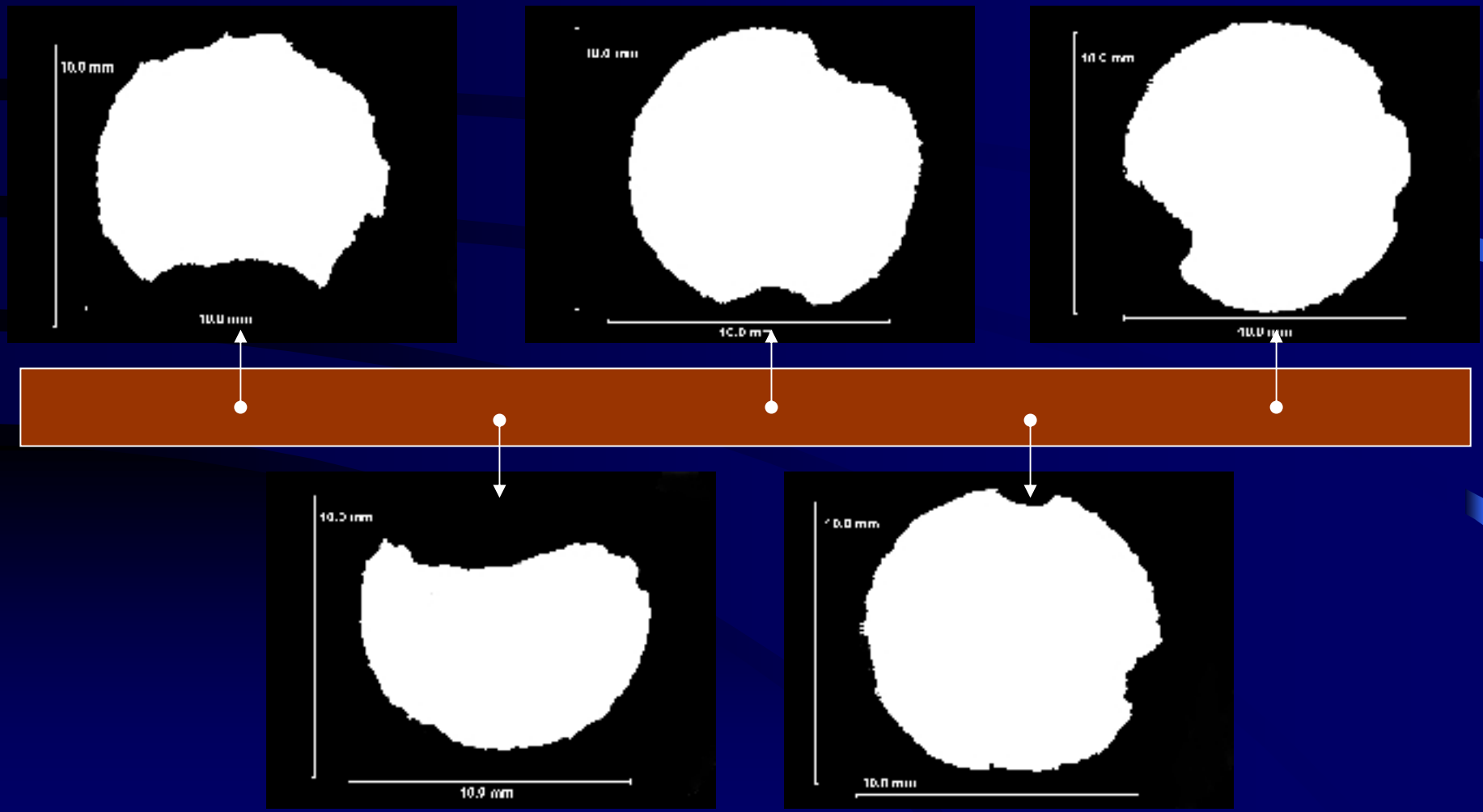
Cylinder Corrosion



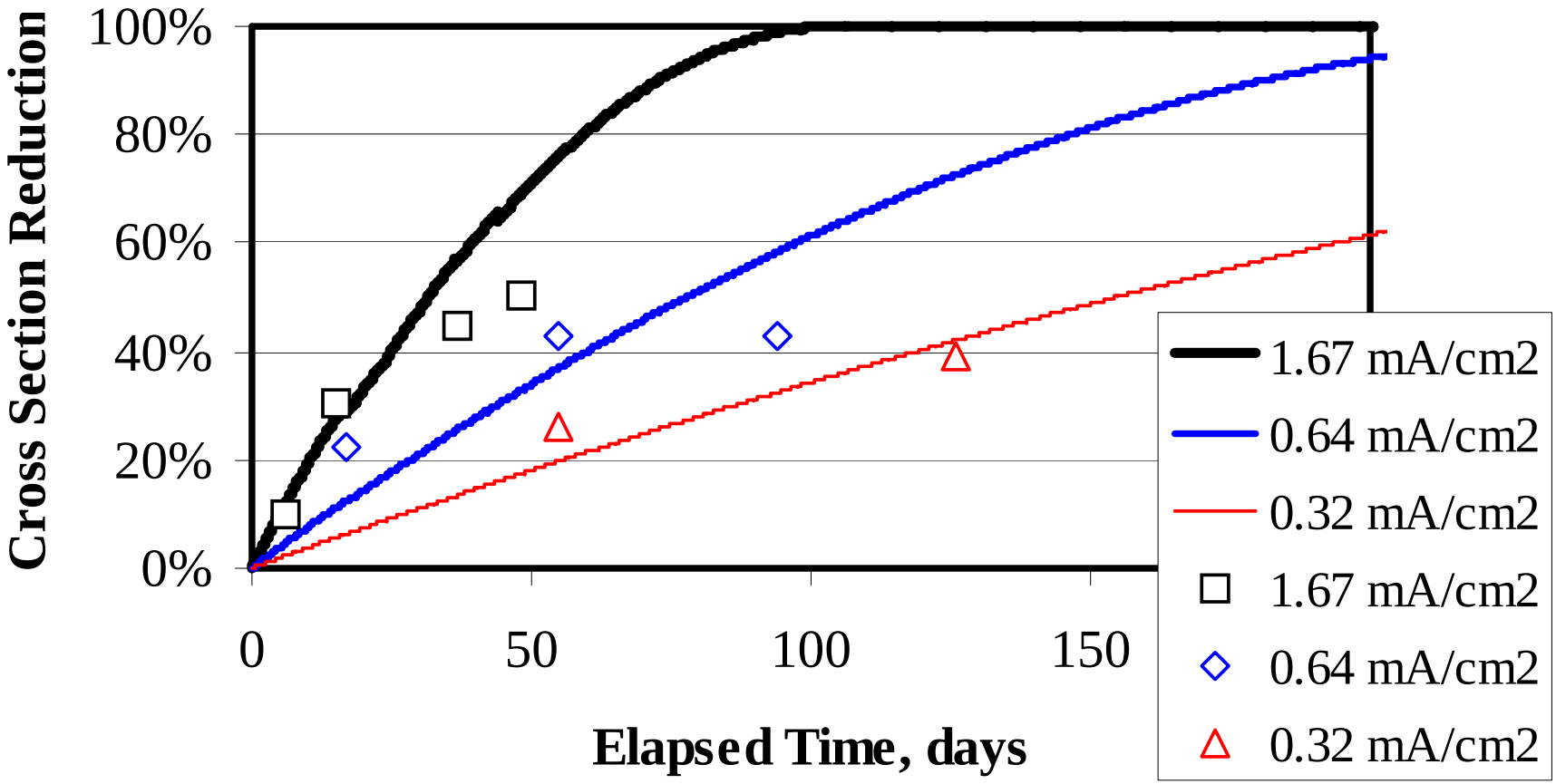
Cylinder Cross Sections
31% Section Loss



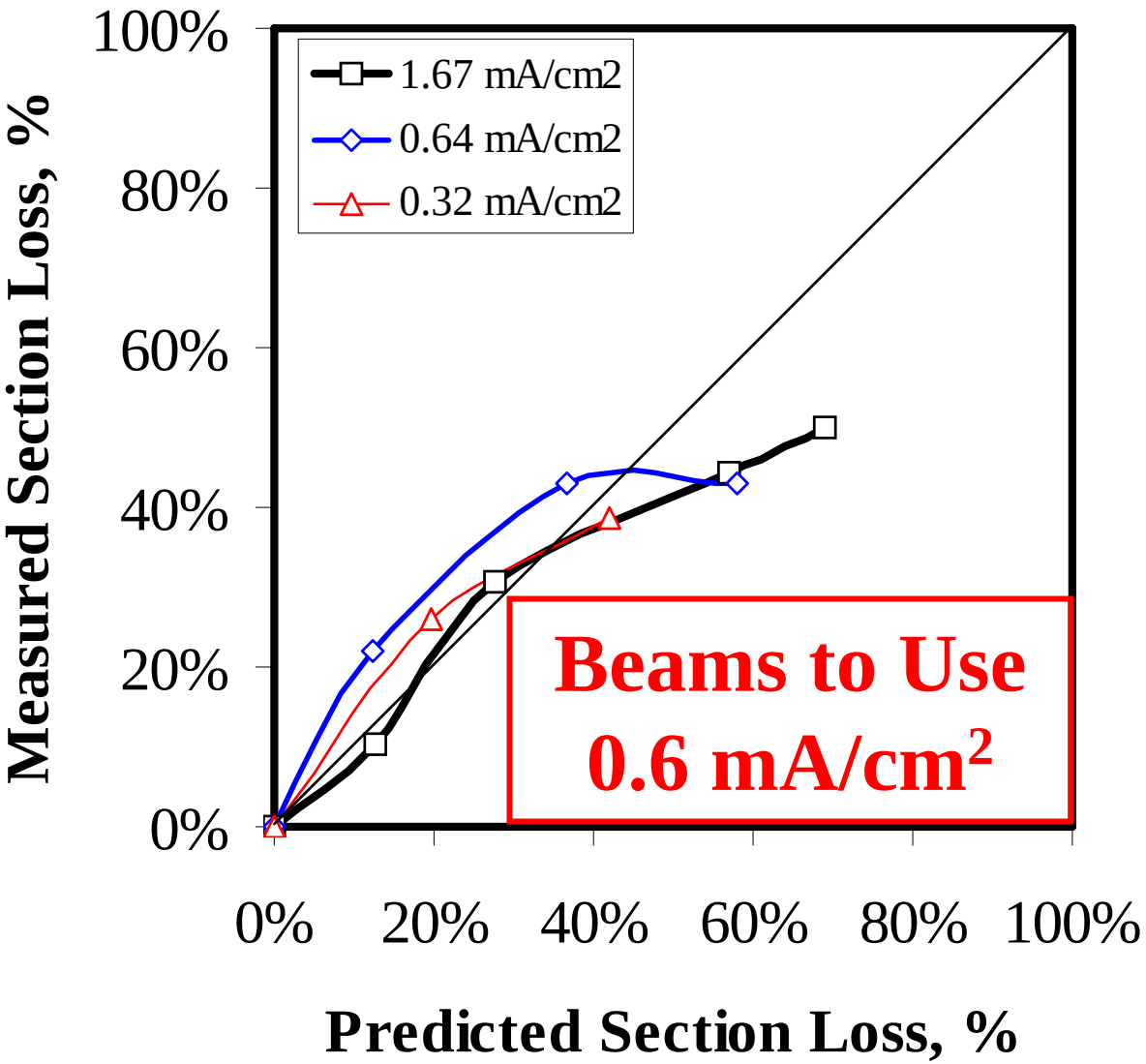
Section Loss Variation
31% Section Loss



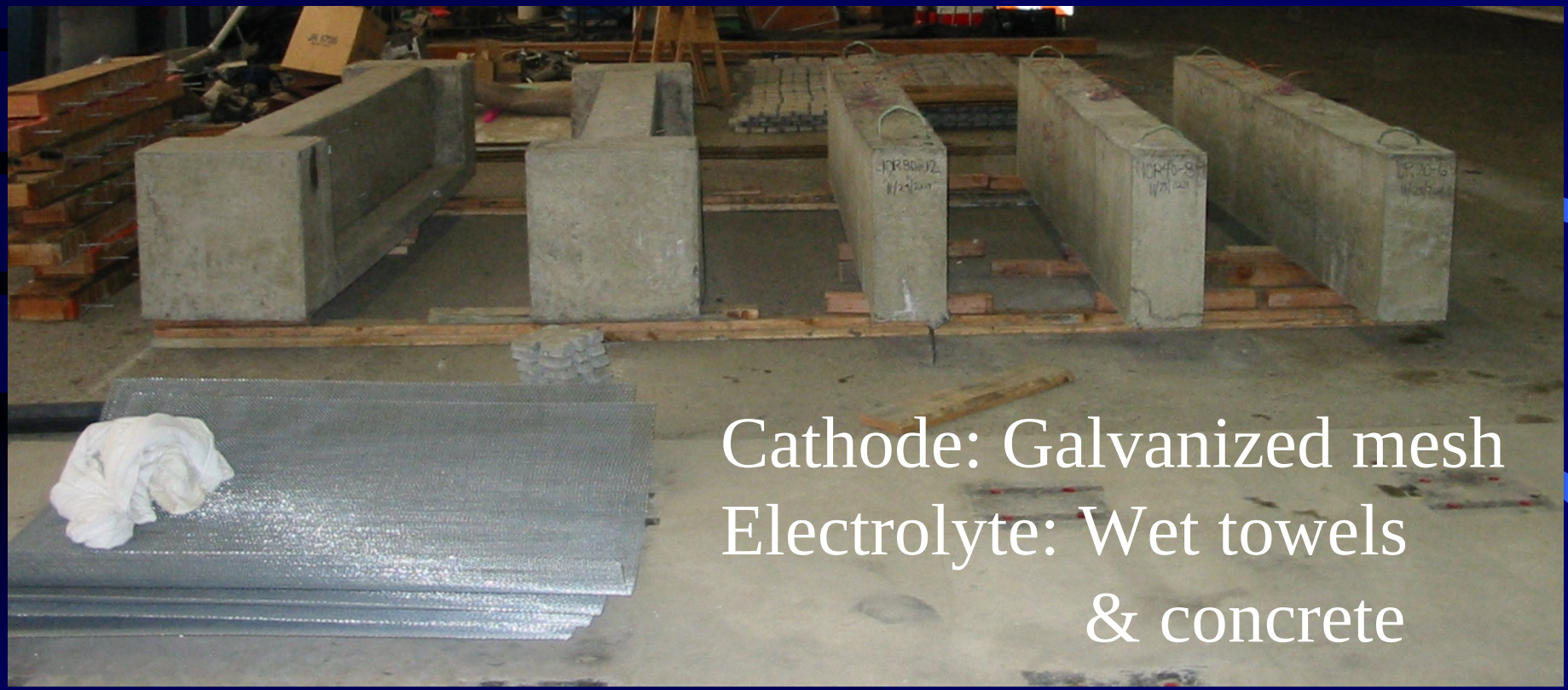
Effect of Current Density



Predicted Section Loss



Beams for Corroding



Shear Strength Testing

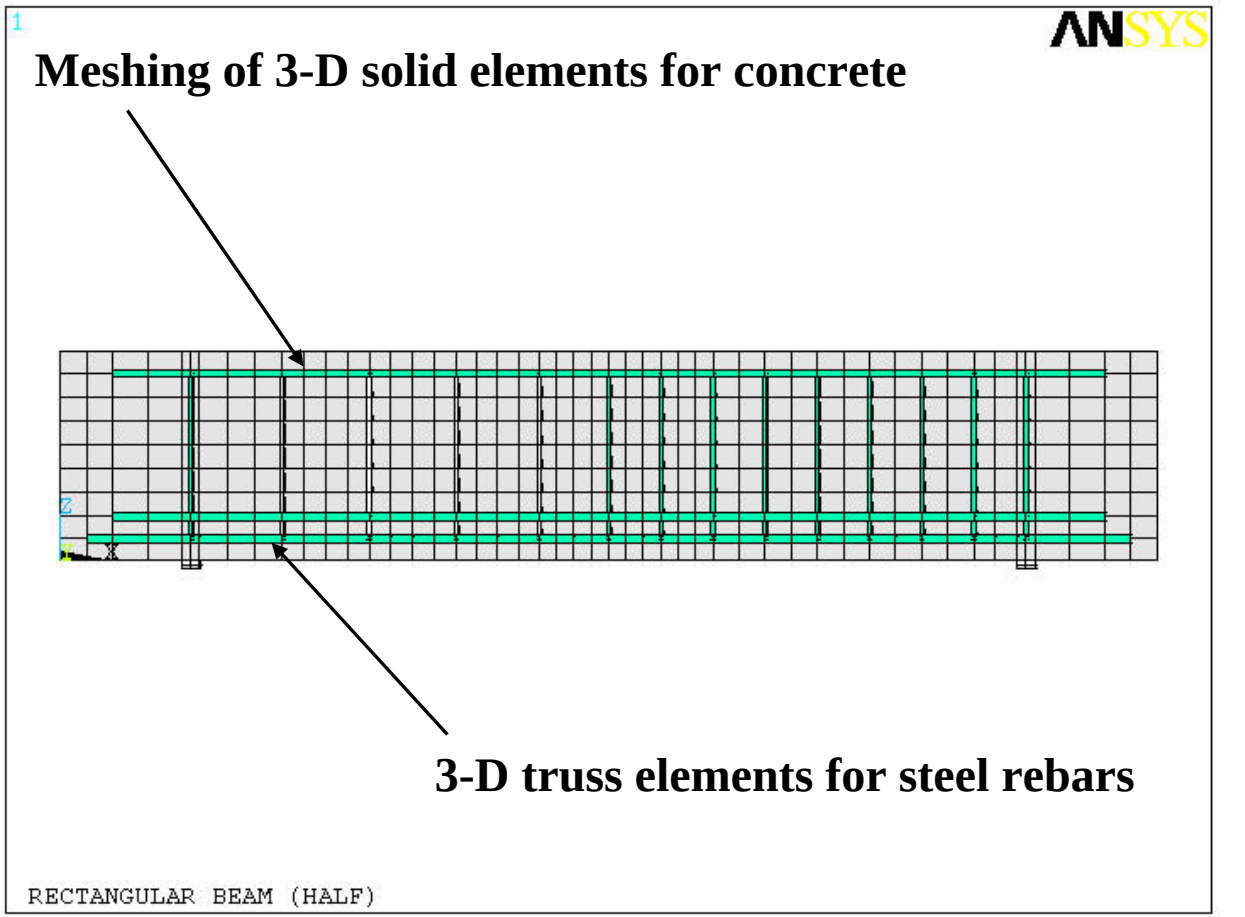
- Destructive tests
- Beams simply supported
- Three point loading
- Instrumentation to measure
  - Applied load and deflection
  - Concrete and rebar strains
  - Crack width
  - Corrosion potentials

Load Frame

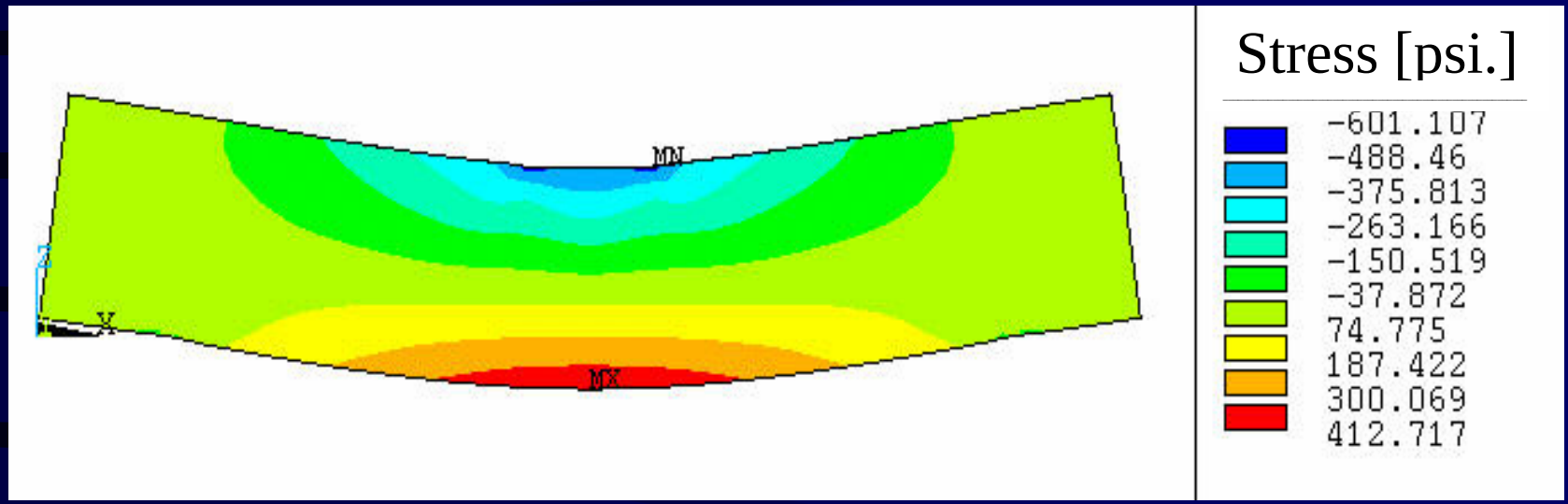
Analysis

- Correlate results to
  - Identify the shear reinforcement damage
  - Assess remaining shear capacity
  - Create a methodology to identify structures likely to suffer premature corrosion damage

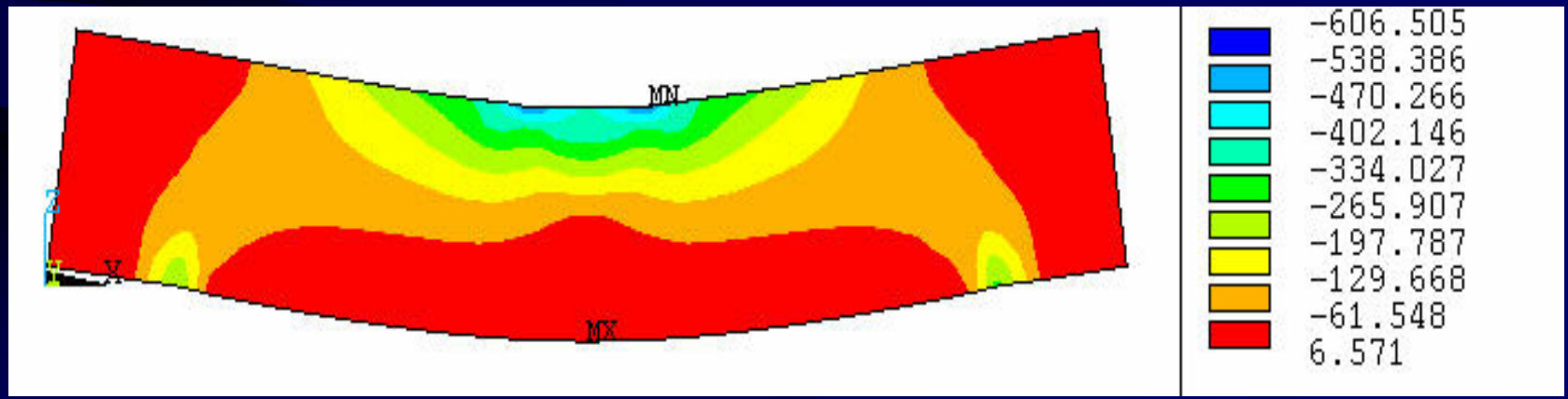
Finite Element Model

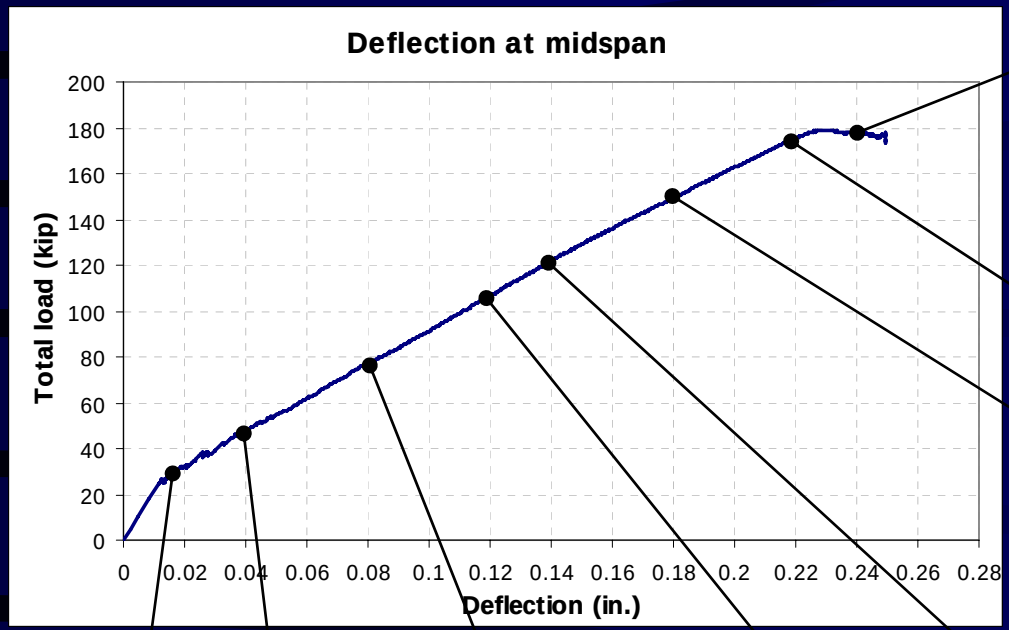


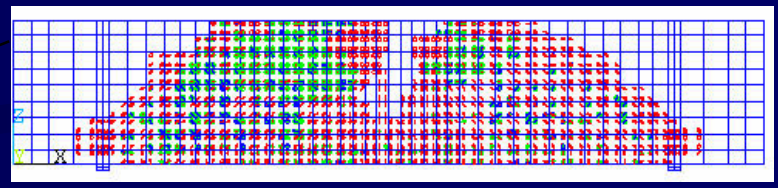
Axial Stress (in-plane)

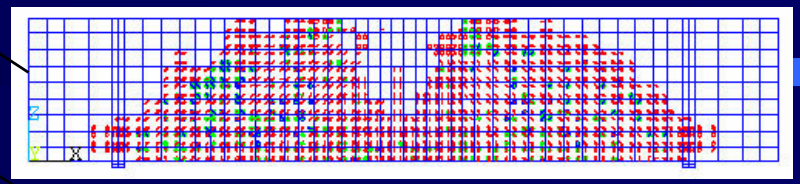


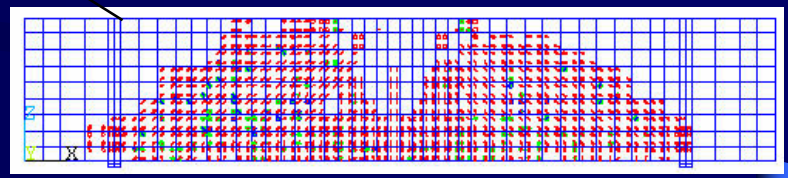
Principal Stress (out-of-plane)

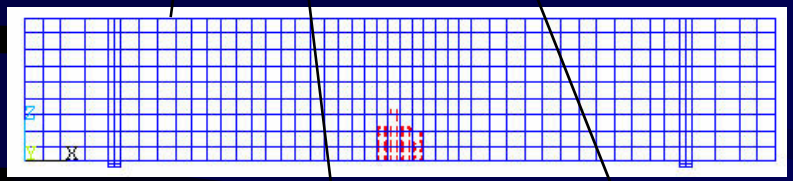


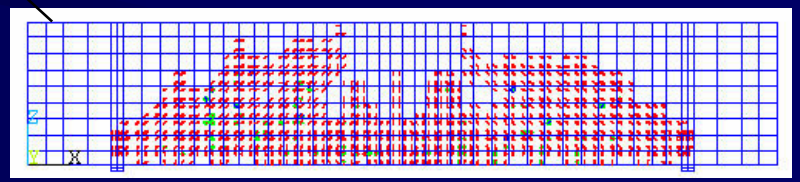


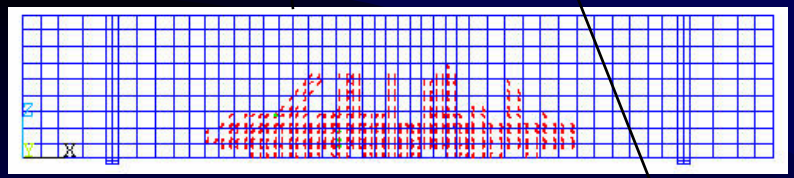


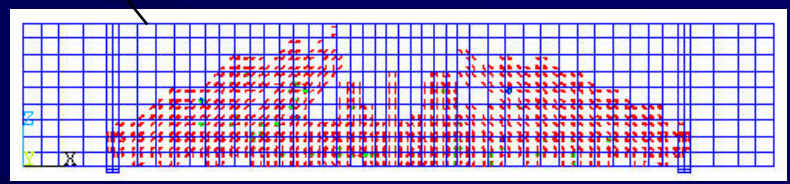


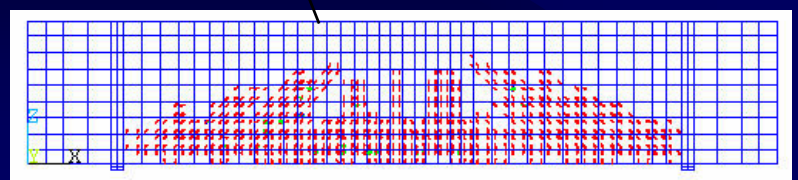












Cracking patterns of the concrete beam up to ultimate load

Translate Results to Practice

- Create a guide for bridge inspectors
- Visual guidelines based on illustrations, photographs and descriptions to broadly specify the corrosion and structural damage of a bridge element
- Further guidelines beyond visual to more accurately specify the damage
- Workshop for designers, engineers, and inspectors

Summary

- ARC and OSU working together on ODOT project to find the relationship between corrosion damage and shear capacity.
- Completed casting of first 6 beams.
- Nearly finished small cylinder investigation.
- Initiating corrosion of 5 beams at 0.6 mA/cm^2
- Goal is to provide tools, including visual examinations, to assess remaining shear capacity